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## CRYSTOSPHEENES OR BURIED SHEETS OF ICE IN THE TUNDRA OF NORTHERN AMERICA.

SHEETS or layers of clear ice have often been recorded as occurring in the alluvial deposits or in the sphagnum swamps of Arctic or sub-Arctic America, and most of the travelers who have made even short visits to the far north have noticed the occurrence of these ice-sheets in small escarpments on the edge of the tundra. I myself observed them in a number of places along the southern edge of the Barren Lands, in the country between the Mackenzie River and Hudson Bay, and drew attention to the fact that some of them, at least, were moving slowly down the gentle slopes on which they were lying. Since coming to the Yukon Territory I have had many opportunities of seeing and examining them in the frozen bogs which cover the bottoms of most of our valleys.

As the mode of formation and growth of these ice-sheets for a long time appeared to be rather difficult to explain, the following remarks with regard to them may be of interest.

The Klondyke gold-bearing district, to which my observations have lately been confined, and in which the deductions here set down were drawn, is a part of a great unglaciated belt or tract of country lying near the middle of the Yukon Territory in Canada, between the glaciated region which extends on both sides of the "Chilcat" or Coast Range of mountains to the south and southwest, and the also glaciated region of the Ogilvie or Rocky Mountain range to the north and northeast. It is a country of high, well-rounded hills and deep, though flaring, valleys, in the bottoms of which flow streams with regularly decreasing grades. On one or both sides of these streams are everywhere deposits of alluvial material, varying from ten to a hundred feet in depth, consisting below of coarse sand and gravel, above which are fine sands with peaty and vegetable material, the uppermost layer, locally known as "muck," usually consisting almost exclusively of sphagnum swamp. The streams flow on beds of the coarser alluvial gravel or sand, seldom touching the underlying rocky floor, and are at present confined in relatively

shallow channels, the sides of which consist of the peaty and finer alluvial material. Ponds or lakes are conspicuously absent.

The surface of the whole country, whether composed of "muck," gravel, or rock in place, is almost everywhere permanently frozen, and while as yet comparatively few shafts have been sunk through this frozen layer, the evidence at hand would seem to show that it



FIG. 1.—Ice formed by spring water in winter.

has a thickness varying from forty or fifty feet on the higher, uncovered parts of the hills, to two hundred feet in the moss-covered bottoms of the valleys. Here and there, however, there are unfrozen channels in the otherwise frozen layer, through which springs issue from the sides of the hills, carrying water from the deeper saturated, and unfrozen ground through the frozen layer to the surface.

Most of the known springs issue from the rock above the surface of the alluvial deposits in the bottoms of the valleys, but some have been exposed by mine workings beneath the ordinary surface levels. They all discharge more or less water throughout the year,

their flow being but slightly, if at all, affected by the conditions of the weather, or even by the most extreme seasonal changes of temperature. In summer those that issue from the rock above the alluvial deposits discharge over the surface into the nearest brooks or rivers, and, except where used as local supplies of clear cold water for household purposes, are rarely noticed; but in winter, when the thermometer occasionally falls as low as  $-60^{\circ}$  F., the water flowing out into the cold air freezes within a comparatively short distance, and by the close of the winter it may have formed a mass of ice many feet in thickness. These ice-masses are locally known as "glaciers," and where they form along the lines of roads are often serious obstructions to travel.

But, in addition to these masses of ice formed on the surface every winter, and which regularly melt away during the following summer, other masses are formed beneath the surface in such positions that they are protected from the action of the sun and atmospheric agencies; and thus it is possible for them to increase from year to year to very considerable dimensions. These underground masses of clear ice are also locally known in the Klondyke country as "glaciers," but the name "cristosphere" (*κρύσταλλος* "ice"; *σφήν*, wedge") is here suggested for them, as indicating a mass or sheet of ice developed by a wedging growth between beds of other material, while the name "cristocene" (*κρήνη*, fountain), is suggested for the surface masses of ice formed each winter by the overflow of springs.

Cristospheres are formed by springs which issue from the rock under the alluvial deposits that cover the bottoms of the valleys. As a rule, they occur as more or less horizontal sheets of clear ice, from six inches to three feet or more in thickness, lying between layers of "muck" or fine alluvium, usually where the "muck" is divided horizontally by a thin bed of silt or sand; and most of them, as far as my observation goes, are from two to four feet below the surface, though some are deeper. In area they differ greatly. One observed by the writer on the shore of Daly Lake, near the southern edge of the Barren Lands west of Hudson Bay, seemed as if it might underlie a square mile or more, while many of those in the bottom lands of the gold-bearing creeks of the Klondyke district vary in length from a hundred to a thousand feet, and in width from fifty

to one or two hundred feet, as shown by shafts sunk through them at various places.

Speaking generally, these ice-sheets are of very even and regular thickness throughout, though they are not strictly horizontal, but approximate closely to the slope of the surface under which they lie. For instance, the city of Dawson is built on an alluvial bottom land declining gently from the base of a steep hill to the banks of the Yukon and Klondyke Rivers, and a crystosphere which here underlies the surface at a few feet beneath it seems to have about the same slope. In another case a crystosphere was encountered on a mining claim on Hunker Creek three feet below the surface, and it was traced for five or six hundred feet down the valley, being everywhere at practically the same depth, while the surface itself had a slope of about one in a hundred, so that this apparently level sheet of clear ice was five or six feet higher at its upper end than at its lower. Examples of this kind could be multiplied almost indefinitely, showing plainly that these ice-sheets do not partake of the character and attitude of frozen ponds or lakes.

While these crystosphenes, or so-called "glaciers," are usually of the nature of nearly horizontal sheets, occasionally they occur as veins or dikes of ice rising through the bed-rock into the overlying gravel. Two such veins of ice were very well exposed in the underground workings on mining claim No. 39, below Discovery on Hunter Creek, where they evidently represented the former course of a spring, which had changed its point of discharge. More or less vertical masses of ice are also sometimes met with in the gravels themselves, indicating the positions of former water channels from the bed-rock toward the surface.

In the majority of cases crystosphenes are in the vicinity of springs that can be plainly seen issuing from the bases of the neighboring hills, but in other cases no such springs are apparent. In these latter cases, however, wherever the gravel has been removed, and the underlying rock has been exposed, springs have been found. While studying the origin of the crystosphere 600 feet long, already mentioned as occurring on Hunker Creek, no springs were apparent in the immediate vicinity, and at first it seemed as if the ice must have been formed from water flowing from a spring three or four hundred yards farther up the valley; but finally a little trickling

stream was found issuing from the rock several feet below the level of the top of the alluvial deposits. This was the source of the water that had formed the ice.

The mode of formation of these underground sheets of ice is therefore somewhat as follows:

Water, issuing from the rock beneath a layer of alluvial material, rises through the alluvium, and in summer spreads out on the surface, tending to keep it constantly wet over a considerable area. In winter, if the flow of water is large, and the surface consists of incoherent gravel, the water will still rise to the surface, and there form a mound of ice. If, on the contrary, the flow from the spring is not large, and the ground is covered with a coherent mass of vegetable material, such as is formed by a sphagnum bog, the spring water, already at a temperature of  $32^{\circ}$  F., rises till it comes within the influence of the low temperature of the atmosphere above, and freezes. This process goes on, the ice continuing to form downward as the cold of the winter increases, until, a few feet below the surface, but still within the influence of the low external temperature, a plane of weakness is reached in the stratified and frozen vegetable or alluvial deposit, such planes of weakness being generally determined by the presence of thin bands of silt or fine sand.

As any outlet to the top is now permanently blocked, the water is forced along this plane of weakness, and there freezes; and thus the horizontal extension of the sheet of ice is begun. While thus increasing in extent, the ice also increases in thickness by additions from beneath, until it has attained a sufficient thickness so that its bottom plane is beyond the reach of the low atmospheric temperature above; after which it continues to increase in extent, but not in thickness or depth.

With the advent of the warm weather of summer the growth of the crystosphene ceases, but the cold spring water which continues to rise up beneath it has very little power to melt it, and its covering of moss or muck, being an excellent non-conductor of heat, protects it from the sun and wind, and prevents it from thawing and disappearing. Thus at the advent of another winter it is ready for still greater growth.

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